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Mongolian Mires: From Taiga to Desert

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Photos by A. SIRIN, plant portraits by T. MINAYEVA

In fond memory of Ivan Gubanov, the premier expert on Mongolian flora, and the top Mongolian herbarium treasurer, whose profound knowledge greatly supported this study.

Abstract: The article presents the first overview of mire diversity in northern and central Mongolia. It discusses information about mires in Mongolia that is available in publications dating back to the nineteenth century. Based on GIS analysis of topographic maps, specialists determined the distribution of peatlands in Mongolia, which cover over 1.7% of the country's total area. During a field excursion in 2003-2004, researchers studied mire features at key sites; these features included position in relief, peat stratigraphy, genesis, and modern vegetation cover. Seven ecological mire type groups were identified for that part of Mongolia: valley meadow-fens in the steppe zone; transitional mires in large valleys in the forest zone; valley sloping fens in the highlands; sphagnum-sedge sloping bogs; forested kettle mires and paludified coniferous forests in the taiga zone; valley transitional mires on permafrost; and highland blanket bogs. This text analyzes a flora list for each mire type in relation to the taxonomic composition and contingent of ecological groups. The broad spectrum of species within mire habitats is considered to be a mechanism of potential response by plant communities to fluctuations in ecological conditions. Mires of the surveyed territory are actively used as pastures and in some places as arable lands. They are affected by overgrazing and climate change.

Key words: mire, peatland, Mongolia, sedge fen, sloping fen, kettle mire, blanket bog, permafrost, pasture, desertification, wise use.

Looking for Mires in the Kingdom of Steppe, or "By Way of a Preface"

One might say that, in people's imaginations, Mongolia is a land of steppes and deserts. But mire scientists seek out mires everywhere, and so we did in Mongolia. Our enthusiasm was buoyed by descriptions of Mongolian mires, which we encountered sporadically in old publications. In a publication dating back to 1956, LAVRENKO wrote:

"In the upper flow of the Orkhon River, below the site of the former Erdene-Zuu Monastery, there is a vast massif of fen mires, covering several thousand hectares. It occupies the lower terrace of the Orkhon Valley, which is very wide at that part. The elevation of that mire massif is 1.400 m above sea level. A vegetation sketch was carried out on August 24th 1951, at a point 1.5 km from the river bank. The main association was described by dominants – hummocks with *Carex parva*[1] and hollows with *Carex dichroa* (+ *Utricularia intermedia*). Also found on the hummocks were: *Deschampsia caespitosa*, *Agrostis mongolica*, *Carex orbicularis*, *C. karoi*, *C. coriophora*, *C. enervis*, *Eriophorum polystachyum*, *Equisetum palustre*, *Saxifraga hirculis*, *Gentiana pseudoaquatica*, *Gentiana barbata* and *Leontopodium* sp. (sporadically). The area between the hummocks was covered with standing water. Here, *Carex dichroa* dominates, *Utricularia interme-*

[1] In citations, plant names are presented as they appeared in the original text.

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Photo 1: Some parts of the sedge fen in the Orkhon valley could look the same 70 years ago as E.M.LAVRENKO described it.

dia (already showing hibernating buds) is abundant, and *Carex orbicularis* is present. Sometimes, among that association, small and shallow lakes can be found, where aquatic species are quite common, particularly *Utricullaria intermedia* and *Myriophyllum sp.*; here, *Utricularia vulgaris*, *Utricularia minor*, *Potamogeton heterophyllus* and *Chara sp.* are less numerous."

Full with the hope that we, too, might behold beautiful sedge fens blanketing thousands of hectares, we started our expedition from precisely that point, located one full day's travel from Ulaanbaatar. Here, we encountered the first deviation from the description above: the "former Monastery" is "former" no more. The monks are back, and the monastery is very busy. It's no wonder. In antiquity, this was the capital of Mongolia. The second difference we observed was both very dramatic and very disappointing. The description of what we saw "...in the upper flow of the Orkhon River, below the site of the former Erdene-Zuu Monastery..." follows below:

Photo 2: Nowadays the most area of the Orkhon valley is covered by overgrazed steppe-like vegetation.

"Along the river, we saw dry willow trees here and there, which appeared to be completely dead. The entire lower terrace of both the left and right banks between the two channels of the Orkhon River was a dry, brown-green surface, dotted with black and yellow spots; small, round hummocks; and sparse small pools. The brown-green surfaces were comprised of patches of very small sedges; the black spots were comprised of bare peat, sometimes with very abundant champignons; the yellow spots were once hollows, filled with sedge-horsetail peat, and now covered with *Halerpestes sarmentosa*[2], a type of buttercup. The hummocks, from which samples were taken, presented the remains of the lower parts of shoots typical for *Carex cespitosa*. Small pools still contain some aquatic vegetation. It is goes without saying that, in that area, thousands and thousands of yaks, cows, and horses were grazing. Local people told us that in the past, traversing the mires on horse wasn't even possible. And now, local people put their yurts right where a hollow-hummock complex was a couple dozens years ago."

We were extremely disappointed, but we did not suspend our survey, and decided to follow our scientifically based plan. And for our persistence, we were awarded later on; in areas where permafrost still exists, we observed beautiful fen vegetation just like that described by LAVRENKO in the 1950s.

[2] The taxonomy of vascular plants is presented according to GUBANOV (1996). The nomenclature of species added to the list (marked by an asterisk) is presented according to CZEREPANOV (1995). The nomenclature of Bryophytes is presented according to TSEGMED (2001).

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How Many Mires are Known to Exist in Mongolia?

In our examination of all known inventories of global peat resources, we found the peatlands of Mongolia to be poorly represented. They are not presented in Global Peat Resources by LAPPALAINEN (1996) and are under-represented (by 50 km²) in Wise Use of Mires and Peatlands by JOOSTEN & CLARKE (2002). Mongolian peatlands are considered to be diverse, paludified lands and shallow peat deposits sometimes exceeding square 3.000 ha in World Peat Resources by MARKOV et al. (1988). KATS (1971), in his Mires of the World, reports on reed and sedge fens distributed along Mongolia's mountain ridges. Sedge fens are associated with permafrost in river valleys higher than 1.800 m. Peat deposits are very shallow (no more than 20 cm in depth), and moss cover by *Drepanocladus* sp. is sometimes found. TUREMNOV (1976), in his review of peat resources, refers to OBRUCHEV's description of vast and unpassable mires in the Onon and Shilka Valleys in eastern Mongolia. The same author described fragmental sedge fens on permafrost west of the Hingan Ridge, and on the lower plateau of the Large Hingan and in the Khangay Mountains.

Recently, an estimation of peatland distribution in Mongolia was carried out within the framework of the Global Peatland Initiative Project (MINAYEVA et al. 2004). We first endeavored to determine the area that might potentially contain peatlands. Our estimation was based on the Map of the Ecosystems of Mongolia, scale 1:1,000.000 (GUNIN & VOSTOKOVA 1995), and demonstrated that landscapes with peatlands could cover up to 100.000 km², or 7% of the country's territory. Later, all peatlands were delineated using topographic maps, with a scale of 1:200.000. The potential of Russian topographic maps in conducting mire inventories has been demonstrated before (SIRIN & MINAYEVA 2001), and the maps used for this study were additionally supported by a scheme of deposits presented on the map's obverse. GIS technology offered the opportunity to determine the area of each peatland, its altitude, and its position in the landscape. The number of points was further checked in the field. Map-based inventory demonstrated that peatlands exist in Mongolia and that peat-covered areas might cover up to as much as 2% of the country's total territory (Tab. 1). The actual distribution of peatlands and mires appeared to have been very similar to that predicted through analysis of the ecosystem map. They are bound to foothills and mountains within forest steppe, taiga, and mountain tundra, and are common in mountain river valleys in the steppe zone (Fig. 1).

The significant area that the mires occupy, as well as the their potential role in water supply and biodiversity maintenance, are the strong arguments for urgently conducting an inventory of Mongolian mire diversity and peat resources, ecosystem functions, threats to them, and prospects for mire conservation and their wise use.

Tab. 1: General Information on Mongolian Peatlands.

Country area	1,566.500 km²
Peat-covered area	27.200 km²
Percentage of country covered by peat	1.74%

How Diverse are Mires in Mongolia?

Background Information

Geographically fragmented data on Mongolian mire vegetation, diversity, and distribution is available mainly from vegetation inventories conducted by the following Russian scientists in nineteenth and twentieth centuries: PRZHEVALSKY (1875, 1883, 1888), POTANIN (1881-83, 1893), PALIBIN (1901), KOMAROV (1905, 1908), SAPOZHNIKOV (1911), GRUM-GRZHIMAILO (1914) and PAVLOV (1929a). Very little information from that period is available in English, only a floristic work by PAVLOV (1929b) and a sketch of vegetation and flora in the area

Fig. 1: Distribution of Peatlands in Mongolia.

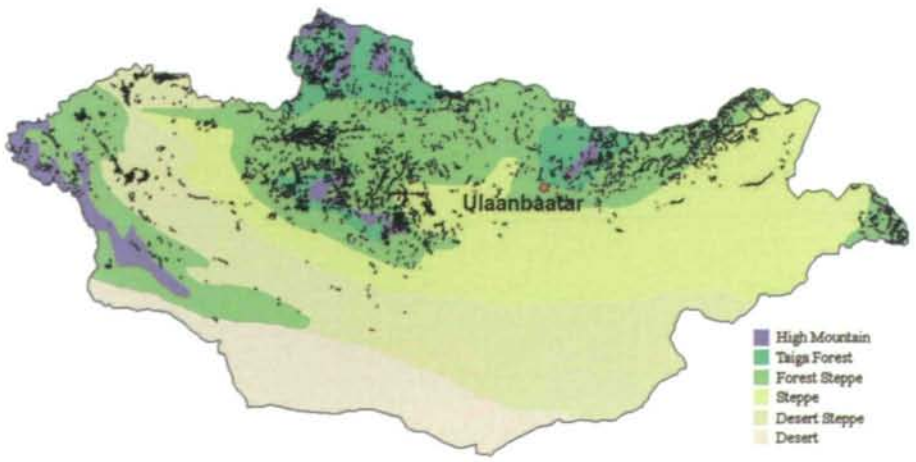

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Photo 3: Treks through the mires are not easy and sometimes insidious ; the Uver-Teel River valley.

northwest of Hovsgol Lake and Darhad Kettle by PRINTZ (1921). These data were compiled and later presented – partly by PAVLOV (1929) and finally by YUNATOV (1950). But these studies focused on vegetation in general, one must carefully comb the text for information on mires. Some additional information can be found in a review by PETROV (1966-67). LAVRENKO (1956) compiled different descriptions of mires in his overview of Central Asian mountain sedge fens. In the latest vegetation survey, peatlands are classified primarily as "grass-sedge" swamps in valleys and intermontane kettles, or as tundra communities in highlands (GUNIN et al. 1999). There are some recent publications on floristic findings of mire species, primarily of vascular plants (GUBANOV 1996). A few paleo-ecological studies were carried out based on peat material (DINESMAN et al. 1989).

Photo 4: Treks through the mires are not easy and sometimes insidious; Darhad Kettle valley.

Trek through the mires

Not being satisfied with the fragmented information on mire diversity based on cartographic data and available publications, we plotted an expedition route, which was taken by Mongolian and Russian scientists during the periods July-August 2003, and June-July 2004. In 2003, the expedition covered more than 4.000 km^2 over plain highlands and mountain regions of the central and northern parts of Mongolia, representing steppe and forest zones and high mountain areas. Seven key regions were studied: the Orkhon River Valley (surrounding the Ogii Nuur Ramsar site), three sites within the East and Central Khangay Mountains, the Ider and Tesiin Gol River Valleys, and the Darhad intermontane Valley. In addition, in the steppe-forest, sub-taiga, and taiga zones of central-northern Mongolia, mires were thoroughly described in the Khentey Mountains. In 2004, fieldwork focused on the eastern part of the country in the Khentey piedmonts, along the Eeren-Daba Ridge, and in the eastern Mongolian lowlands. Key sites were situated along the Onon and Ulz-gol River Valleys and partly in the Kerulen and Ulz-gol Interfluves.

Within each key region, the diversity of mires and their general description were sketched out, including characteristics such as vegetation type, hydrological conditions, peatland position within the relief and landscape, and their land use and status. Testing sites within each key region were studied in detail: Ecological profiles and ecosystem mapping were made; geobotanical relevees, including floristic sampling were carried out; peat pore water was tested (levels, pH, electric conductivity); peat and peaty soils were described and sampled for bulk density, ash content, ^{14}C dating, macrofossil botanical composition, and the degree of decomposition. In the current sketch of Mongolian mires, not all of these numerous data are presented, but they were very useful for

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understanding the origin and nature the ecosystems described below.

Diversity of Mire Types

Mires in Mongolia are very difficult to describe. The challenge lies in the fact that they really sometimes comprise a disappearing landscape type. As we will later see from flora analyses, mires can be temporarily replaced by neighboring communities, depending on climactic conditions. This offers the opportunity to consider mires more broadly than we are accustomed to doing.

Diversity is high, and depending on landscape type and geomorphologic position, we were able to identify several consistent mire types. We did not develop a comprehensive classification system, and instead base our types on the traditional Russian complex landscape approach to mire type identification. We begin our description with "lowlands" and ascend to the highlands, covering the following mire types: valley meadow-fens in the steppe zone; transitional mires in large valleys in the forest zone; valley sloping fens in the highlands; sphagnum-sedge sloping bogs; forested kettle mires and paludified coniferous forests in the taiga zone; valley transitional mires on permafrost; and highland blanket bogs.

Valley Meadow-fens in the Steppe Zone

Valley meadow-fens are found in steppe and forest steppe zones around mountain lakes and in large river valleys, such as the valleys of the Orkhon, Muren, Tesiin Gol and Ider Rivers. In such valleys, trees are nearly absent, and steppe meadows neighbor sedge fens. Such landscapes might be called "lowlands," with some assumption. These lake kettle mires and vast lowland valleys are found at an elevation of 1.200 – 1.800 m above sea level. The mires here primarily represent the remains of former large fens with tall sedges; this can be deduced from the hummock remains, from the composition and age of bottom peat deposits, and from stories of local nomadic people.

Despite the fact that the peat surface can be extremely dry in the summertime, peat depth is still considerable, up to 70 cm. These mires are sedge fens, but which are

Photo 5: The Orkhon valley fen is so dry nowadays, that nomadic people built their houses directly on the former mire.

sometimes salty. Usually, hummock-hollow structure is present. The hollows are filled with peat, which is still wet. Bottom peat layers vary significantly in age, depending on the history of the valley, and are figured to date back to 200 to 1.000 years before present (BP) (^{14}C non-calibrated dates). PAVLOV (1929) described these lowland valley landscapes as vegetation complexes with pools, mires with hummocks, meadows on flat loamy sites, loamy-boulder ridges with meadow-steppe vegetation, and pure boulder sites with steppe-desert vegetation.

The Orkhon Valley (N 47°27', E 102°48' – 47°44', 102°41') sedge fens are

Photo 6: The numerous champignons precisely mark rich peat soils.

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Photo 7: In the Tesiin Gol river valley one hardly can find running water in former riverbeds. Camels bring the additional feature of desertification here.

relatively young, with basal peat age not exceeding 250 years (240±100 GIN–12811; 230±70 GIN–12815). Presently, though, it is in the stage of depaludification cycle. We also found a number of pools with typical aquatic flora: *Eleocharis palustris*, *Hippuris vulgaris*, *Lemna minor*, *Myriophyllum spicatum*, *Potamogeton perfoliatus*, *Ranunculus natans*, *Scirpis hippoliti* and *Sparganium stoloniferum*. The meadow and meadow-steppe sites were more extensive than they were in the past due to the fact that parts of mires had dried. Key species at those sites include *Artemisia mongolica*, *Leontopodium campestre*, *Leontopodium ochroleucum*, *Trifolium lupinaster*, *Aconogonon angustifolium*, *Allium ramosum*, *Arenaria capillaris*, *Artemisia laciniata*, *Bromopsis inermis*, *Carex duriuscula*, *Carex parva*, *Equisetum arvense*, *Galium verum*, *Glaux maritima*, *Heteropappus hispidus*, *Hordeum brevisubulatum*, *Iris lactea*, *Inula britannica*, *Koeleria cristata*, *Medicago lupulina*, *Odontites vulgaris*, *Oxytropis glabra*, *Poa attenuata*, *Poa pratensis*, *Potentilla pensylvanica*, *Silene repens*, *Stipa krylovii*, *Taraxacum leucanthum*, *Taraxacum mongolicum* and *Taraxacum officinale*. The driest parts provide habitat for such species as *Artemisia adamsii*, *Artemisia frigida*, *Chenopodium aristatum*, *Cleistogenes squarrosa*, *Lappula intermedia*, *Salsola collina* and *Thymus gobicus*. Mire vegetation itself can be found in hollows, which are still filled with peat that is saturated by water. Here, we find typical mire species such as *Baeothryon pumilum*, *Carex atherodes*, *Carex bipartita*, *Carex delicata*, *Carex dichroa*, *Carex orbicularis*, *Carex vesicata*, *Cicuta virosa*, *Cirsium esculentum*, *Epilobium palustre*, *Euphrasia pectinata*, *Glyceria triflora*, *Juncus biglumis*, *Juncus gerardii* and *Ranunculus repens* including halophytic species: *Butomus umbellatus*, *Chenopodium album*, *Halerpestes salsuginosa*, *Knorringia sibirica*, *Leymus chinensis*, *Oxytropis salina*, *Plantago major*, *Polygonum aviculare*, *Potentilla bifurca*, *Triglochin maritimum* and *Triglochin palustre*. Sites with gravel and boulders harbor typical xerophytic flora: *Artemisia adamsii*, *Artemisia frigida*, *Carum carvi*, *Chenopodium aristatum*, *Cleistogenes squarrosa*, *Lappula intermedia*, *Salsola collina*, *Saussurea amara*, *Stellaria dichotoma* and *Thymus gobicus*. All habitats are connected by species with broader ecology like *Agrostis mongholica*, *Halerpestes sarmentosa*, *Carex enervis* and *Potentilla anserina*.

Photo 8: Peat deposits still are deep and fill in all hollows.

Sedge fens in Tesiin Gol (49°12', 98°12') Valley are similar in type, but they adjoin salty lakes and salt marshes. The "mire" history of that landscape is somewhat longer than that in the Orkhon Valley, and dates back to 900±60 years (GIN–12823). The primary peat-forming material is comprised of sedge macrofossils, in the beginning *Carex saxatlis*, replaced later on by *Carex schmidtii*. Green moss macrofossils are very sparse in the peat. The modern aquatic and mire flora is more diverse compared to that in the Orkhon Valley and also contains additional species like *Beckmannia syzigachne*, *Carex schmidtii*, *Hordeum brevisubulatum*, *Parnassia*

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palustris, *Poa palustris*, *Ranunculus longicaulis* in mires and *Batrachium eradicatum*, *Catabrosa aquatica*, *Eleocharis palustris* and *Potamogeton compressus* in the pools. Halophytic flora was enriched by *Pedicularis dasystachys*, but *Triglochin palustre* was not found here. West Khangay is connected with the Large Lakes Kettle, which, in the past, may have been a source of wet air masses (YUNATOV 1956, p.143). Now, the Booreg-Delig sands of that kettle, as well as the southern river valleys connected with the Gobi Desert, have become corridors to the West Khangay Valleys for desert species.

Sedge fens in the steppe zone of eastern Mongolia in the Ulz-gol and Onon Valleys are often connected with saucer shaped lakes in valleys and oxbows and are fed by groundwater discharge. As a whole, the river valleys present a combination of steppe, meadow, dry peatland, mire, lake, and pond habitat types. The composition of vascular plant species is characterized by the relatively low participation of meadow and steppe species. The community structure is also slightly different; as in the Orkhon River Valley, we found many dry peat patches with steppe species, but a significant part of habitats are still wet, with tall sedges (*Carex rostrata* and *Carex acuta*), mire species (*Eriophorum polystachyon*, *Eriophorum gracile subsp. asiaticum*, *Equisetum palustre*, *Cicuta virosa*, *Agrostis stolonifera*, *Poa palustris* and *Naumburgia thyrsiflora*) and willows (mainly *Salix ledebouriana*) dominating. Peat depth in living mires normally does not exceed 0.7 m. Another particularity is the presence of the Dahuric biogeographical species group, including *Carex brunnescens*. Such mires are described from the kettle of Galutyn Nur Lake in the Ulz-gol River Valley (49°43' – 117°17') and alongside small lakes in the Onon River Valley (48°41', 110°21' – 48°45', 110°10').

The described mires of large valleys still carry specific mire biodiversity and valuable paleo-ecological information in their peat deposits. Both the Orkhon and Tesiin Gol Rivers Valleys have a significant portion of dry steppe flora species (Fig. 3). Presumably, mires here had entirely lost their ability to maintain peat accumulation, water storage, and landscape integrity (against erosion). In eastern Mongolia, there are still some wet habitats among valley peatlands, and mires there are close to the type described immediately below.

Photo 9: The Huderijn-gol River valley with tall sedges and birch fens.

Transitional Mires in Large Valleys in the Forest Zone

Khentey belongs to a different biogeorgaphical province than Khangay. Usually it is considered, together with Hovsgol Lake and Darchad Kettle, as part of the Sayan Ridge. At this point Zabaikalie taiga penetrates into the Mongolian Gobi (YUNATOV 1950). In the Khentey Mountains, at medium elevations (600–800 m), wide river valleys, such as the Huderijn-gol and Ero River Valleys (49°47', 107°29' – 49°49', 107°28'), can be found. Vegetation at this elevation in Khentey is considered to be forest steppe. Fens here are not as dry as in steppe regions, but the percentage of steppe and meadow vascular plant species is nevertheless still high (Fig. 3). The more humid climate, groundwater discharge, and temporary flooding by the river create good conditions for peat accumulation and mire vegetation development. Peat deposits are usually found directly in the valley alongside its gentlest slope. Peat sometimes reaches 1 meter and the age of the basal layer varies from 180 to 1.500 years BP (GIN–12831 170±60, 30 cm; GIN–12832 1520±40, 45 cm). Mires here are typical tall sedge fens with green mosses. Sparse birch trees (*Betula platyphylla*) reaching 5–7 m in height, and willows (*Salix pseudopentandra*, *Salix caprea*

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Photo 10: The spring mires in valleys of the Khentey Mountains.

and *Salix berberifolia*) make attractive habitats for sciophytic forest and meadow species, like *Achillea asiatica*, *Allium schoenoprasum*, *Anemone dichotoma*, *Artemisia integrifolia*, *Bistorta alopecuroides*, *Cacalia hastata*, *Calamagrostis purpurea*, *Cerastium arvense*, *Chamaenerion angustifolium*, *Filipendula ulmaria*, *Geranium wlassowianum*, *Ligularia sibirica*, *Polemonium chinense*, *Ranunculus propinquus*, *Ribes rubrum*, *Sanguisorba officinalis*, *Senecio nemorensis*, *Trisetum sibiricum*, *Vicia amoena* and *Vicia cracca*. Mire species are represented by: *Angelica tenuifolia*, *Carex cespitosa*, *Carex coriophora*, *Carex diandra*, *Carex lasiocarpa*, *Carex schmidtii*, *Carex vesicata*, *Cicuta virosa*, *Comarum palustre*, *Epilobium palustre*, *Equisetum palustre*, *Eriophorum humile*, *Eriophorum polystachyon*, *Euphrasia pectinata*, *Lysimachia davurica*, *Myosotis palustris*, *Naumburgia thyrsiflora*, *Pedicularis karoi*, *Pedicularis resupinata*, *Thyselium palustre*, *Stachys palustris*, *Stellaria palustris*, *Veronica longifolia* and riparian species by *Caltha palustris*, *Eleocharis palustris*, *Equisetum fluviatile*, *Hippuris vulgaris*, *Lemna minor* and *Rumex aquaticus*.

Photo 11: The large part of the Uver-Teel River valley is filled by peat.

In the Khentey piedmonts, at altitudes above 800 m, spring fens can be found. Here, numerous springs formed small rivers and lakes. Mire vegetation settled there many years ago and provided fast growth of peat, which reached up to 2 m. Now, one can observe convexity around water outlets, which is typical for spring mire, and mire is now everywhere around springs, streams, and small lakes. The dominating vegetation is tall sedges, with a prevalence of *Carex cespitosa* and *Carex schmidtii*, and with a mixture of horse tail *Equisetum fluviatile*, green mosses, sparse willows, and birches. The spring fen was described not far from Huder Somon (49°44', 107°19')

Further east from Khentey, similar conditions can be found along the Ereen-Daba (Ereen-Nuuru) and Erman Ridges. Transitional valley fens were described from the Bayan-gol (49°04', 110°52') and Dujche-gol (49°50', 113°48') Valleys and from the intermontane kettle (peat depth more than 70 cm) along the Ereen-Daba Ridge (49°18', 112°35'). The mires here carry more shrubs, birch on drier patches, and willows in wetter areas.

Valley Sloping Fens in Highlands

In Khangay, at elevations ranging from 1.500–2.000 m, most small and medium highland valleys are filled with shallow peat. Mires are presented by sloping sedge-fens and are primarily used as pastures. During most of the year, water level here is low, but peat deposits with depths of 20–50 cm still retain enough water to support pastures. Fens of this type were described in the Uver-Teel River Valley – one of the sources of the Orkhon River (47°13', 101°51'). Peat deposits here date back to 1.500 years BP. While analyzing peat deposits, we observed the inversion of peat layers: older deposits (1.540±90 GIN–12818) were found at the

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depth of 25 cm, while more recent ones (830±100 GIN–12819) were found at the depth of 42 cm. This reflects the highly dynamic processes taking place in these highland mires. From time to time, rainwater or mudflows from above move peat deposits downhill. Such "mire-burst" phenomena have also been described for the Alps.

The fen is fed from both surrounding mountains and from groundwater discharge. The vegetation structure is as follows: In the middle of the valley, along the riverbank, gravel mixed with peat or highly mineralized dry peat is covered by steppe and steppe-meadow vegetation. At the water's edge, and in the water itself, vegetation is poor – only *Batrachium divaricatum* and *Ranunculus natans* were recorded. In dry patches, tussocks of *Iris lactea* and *Festuca rubra* are surrounded by bloodroots (*Potentilla fruticosa*, *Potentilla pensylvanica*), legumes (*Astragalus galactites*, *Astragalus mongholicus*, *Oxytropis glabra* and *Trifolium lupinaster*), and wormwoods (*Artemisia vulgaris*, *Artemisia laciniata*, *Artemisia sericea*). In lower and wetter habitats, sedges with green mosses form mire communities on peat soils.

The following species of vascular plants are typical for the mires: *Agrostis mongholica*, *Angelica tenuifolia*, *Carex atherodes*, *Carex cespitosa*, *Carex cinerea*, *Carex coriophora*, *Carex curaica*, *Carex delicata*, *Carex dichroa*, *Carex dioica*, *Carex lithophila*, *Carex orbicularis*, *Carex schmidtii*, *Cirsium esculentum*, *Eriophorum polystachyon*, *Euphrasia pectinata*, *Gentiana pseudoaquatica*, *Glyceria triflora*, *Halenia corniculata*, *Hordeum brevisubulatum*, *Juncus gerardii*, *Juncus salsuginosus*, *Parnassia palustris*, *Pedicularis karoi*, *Pedicularis longiflora*, *Pedicularis resupinata*, *Potentilla anserina*, *Primula farinosa*, *Ranunculus longicaulis*, *Ranunculus longicaulis* var. *pulchellus*, *Ranunculus repens*, *Salix divaricata*, *Saxifraga foliolosa*, *Saxifraga hirculus*, *Scutellaria scordifolia*, *Sium suave* and *Thyselium palustre*. A significant part of the valley is presented by sedge meadow-fen, which also develops on peat, but which is characterized by lower water levels. Here, we find more meadow and halophytic species, like *Bistorta alopecuroides*, *Bistorta vivipara*, *Blysmus sinocompressus*, *Bupleurum scorzonerifolium* *Carex reptabunda*, *Carex bipartita*, *Carex enervis*, *Carex hancockiana*, *Carex parva*, *Chenopodium album*, *Dracocephalum grandiflorum*, *Knorringia sibirica*, *Kobresia myosuroides*, *Leymus chinensis*, *Ligularia sibirica*, *Ligularia altaica*, *Plantago salsa*, *Potentilla supina*, *Sanguisorba officinalis*, *Thalictrum alpinum*, *Trollius asiaticus*, *Triglochin maritimum* and *Triglochin palustre*. Another interesting element of the vegetation mosaic is the assemblages of relatively high willow shrubs that are in front of the outlets of the main valley tributaries. They indicate gravel deposits mixed with peat. At present, there are no creeks in those small secondary valleys, which are now filled by peat. Because the gravel is situated in the stream fan it offers evidence that small rivers had once been active here. Here, we also recorded

Photo 12: The mire vegetation cover is rather patterned.

Photo 13: Small secondary valleys give chance for remains of larch forests.

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Photo 14: The peat depth in sphagnum sedge mire "Nur" is more than three meters.

more petrophytic species like *Sedum aizoon*, *Spiraea aquilegifolia*, *Stellaria brachypetala*, *Stellaria dichotoma* and species that are typical for rocky valleys *Anagallidium dichotomum*, *Carum carvi*, *Salix ledebouriana*, *Salix saxatilis* and *Saussurea amara*. Some secondary valleys still have running streams and there one encounters the remnants of larch forests *Larix sibirica* which have some peat deposits under the trees.

Sedge fens in highland valleys are the most widely dispersed mire type in Mongolia. According to map analyses, these fens cover approximately 14.000 km², or 1% of the country's total area. These fens are a vital natural resource for Mongolia, as they comprise highly productive pastures.

Photo 15: Paludified forests in mountain stream valleys are formed by five coniferous tree species.

Sphagnum-sedge Sloping Bogs, Forested Kettle Mires and Paludified Coniferous Forests in the Taiga Zone

In northern Mongolia, in the Khentey Mountains, the typical taiga belt is designated by the presence of coniferous forests and sedge-sphagnum bogs. In its origin, the mountain massif belongs to the Sayan Mountains and forms the piedmonts along the Yablonevy Ridge. The vegetation structure and floristic composition of the highlands is very similar to the extensive Russian taiga to the north.

At elevations ranging from 1.900 to 2.300 m, sloping transitional sphagnum-sedge open mires with peat deposits up to 3 m were described in the watersheds of the Huderijn-gol and Ero Rivers. Several mires in the intermontane kettles form a chain (49°38', 107°48'), that further extends into the river valley. Those mires were formed 6.000 years BP (6.310±70, GIN–12564), during the Atlantic Period, when the climate here was presumably wetter and warmer. The loamy deposits beneath the peat contain *Carex juncella* and algae macrofossils. The oldest peat is formed from the same sedge and horsetail. The *Sphagnum* settled very soon (300 years after peat formation had begun) and the subsequent community can be classified as rich fen with relatively fast peat growth. Around 3.500 years ago, the site became more oligotrophic and more or less acquired its modern appearance, with the dominance of *Carex limosa**, *Scheuchzeria palustris*, *Carex rostrata* and *Sphagnum flexuosum*. From the following list of species, one could hardly differentiate, with minor exceptions, this bog from one in northwestern Russia or the Alps: *Carex limosa**, *Carex rostrata*, *Carex pauciflora**, *Comarum palustre*, *Drosera anglica*, *Drosera rotundifolia*, *Huperzia selago*, *Ledum palustre*, *Ligularia altaica*, *Menyanthes trifoliata*, *Myosotis palustris*, *Naumburgia thyrsiflora*, *Oxycoccus microcarpus*, *Oxycoccus palustris*, *Phragmites australis*, *Parnassia palustris*, *Thyselium palustre* and *Scheuchzeria palustris*. In watered hollows, *Utricularia intermedia* is

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found. The moss layer is presented by *Sphagnum flexuosum*, *Sphagnum balticum* and *Sphagnum subsecundum*, with patches of *Sphagnum magellanicum*. The mire is fed by an inflow from surrounding slopes and from precipitation. It has a typical lag area, where groundwater discharge also contributes. This type of lag is formed by birch forested fens with tall sedges and grasses: *Agrostis mongholica*, *Angelica tenuifolia*, *Calamagrostis purpurea*, *Carex cespitosa*, *Carex cinerea*, *Carex lasiocarpa**, *Carex rhynchophysa*, *Carex schmidtii*, *Carex vesicata*, *Cicuta virosa*, *Comarum palustre*, *Deschampsia cespitosa*, *Deschampsia koelerioides*, *Epilobium palustre*, *Equisetum fluviatile*, *Equisetum palustre*, *Equisetum pratense*, *Equisetum sylvaticum*, *Eriophorum polystachyon*, *Filipendula palmata*, *Galium boreale*, *Galium uliginosum*, *Juncus filiformis*, *Ligularia sibirica*, *Menyanthes trifoliata*, *Myosotis palustris.*, *Pedicularis karoi*, *Pedicularis resupinata*, *Phragmites australis*, *Scutellaria galericulata*, *Stellaria dichotoma*, *Viola palustris*, *Viola uniflora*. The other type of lag is found in more oligotrophic conditions and presents birch-spruce-pine-fir mixed stands on transition areas between mires and coniferous forests. Here, we find such typical taiga species as *Carex globularis*, *Linnaea borealis*, *Luzula sibirica*, *Maianthemum bifolium*, *Poa sibirica*, *Rubus arcticus*, *Trientalis europaea*, *Vaccinium myrtillus*, *Vaccinium vitis-idaea*, *Sphagnum* and green mosses.

We were still able to see the process of new mire growth. In the former lake kettle, at elevations of 1.000 m above sea level, we described a small (70–90 ha) sedge forested fen with birch (*Betula platyphylla*) and a combination of *Phragmites australis* and *Ledum palustre*. The moss layer was dominated by *Sphagnum* mosses with hummocks of *Polytrichum*. The peat is relatively fast growing, with rates of one meter of growth every 900 years (900±60 GIN–12830).

In highland rivers and brook valleys and in intermontane depressions, one finds coniferous forests that are typical for the taiga zone, with sphagnum mosses and peat at depths of 30–50 cm. The first layer is formed by the five coniferous species known to be found in that region: *Abies sibirica*, *Larix sibirica*, *Picea obovata*, *Pinus sibirica* and *Pinus sylvestris*. In the lower layer, species of sedges and dwarf shrubs that are typical for the taiga are found in combination with *Sphagnum* and green mosses. These forested mires have been partly destroyed by the gold mining industry and are still under threat.

Photo 16: Beautiful mires in Darhad Kettle are hidden by high mountain ridges

Valley Transitional Mires on Permafrost

Unique conditions for mire development are created in connection with permafrost. The Darhad Kettle area is one of the places in Mongolia known as a permafrost area (50°30', 99°20'). In origin, this mountain area belongs to the Sayan Ridge. The Shishig-gol River, which runs through

Photo 17: Two cotton grass species and *Baeothryon pumilum* make mire landscape in Darhad Kettle similar to the European ones.

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Photo 18: Blanket bogs are covering slopes around the Solongot Pass.

the kettle, is one of the main tributaries of the Yenisey River. The valley is located 1.600 m above sea level and it is surrounded by mountain ridges with elevations of up to 3.000 m: they isolate the kettle from Hovsgol Lake in the east, the Sayan Mountains in the north and west, and the Tesiin Gol and Muren Valleys in the south.

In permafrost areas, water level is always high and water temperature low; this creates ideal habitat where real mire species are out of competition and conditions for peat formation are constant. In the Shishig-gol Valley, relatively vast areas are occupied by very wet sedge fens with green mosses and shrubs. Closer to the river, the peat layer is underlain by gravel with ice at depths of 30–35 cm, where peat deposits are considerably old (2.360±40 GIN–12829). Here, the presence of willow shrubs with a mixture of *Betula fusca* is higher. Further from the riverbank, the peat is deeper, but it is frozen beginning at 50 cm. The deepest sampling that we were able to conduct was at 60 cm, and the peat layer age was also around 2.000 years BP. In this distant part, only dwarf willows present and the mire surface looks like a hummock-hollow complex. The form of complex elements is rather irregular. Hollows are watered and dominated by *Carex coriophora*, *Carex curaica*, *Carex dichroa*, *Carex orbicularis*, *Carex rigidioides*, *Carex vesicata*, *Eriophorum polystachyon*, *Eleocharis palustris*, *Juncus salsuginosus*, *Pedicularis longiflora*, *Triglochin maritimum* and *Utricularia intermedia*. The hummocks are roundish in shape, of varying sizes, and with the dominance of *Angelica tenuifolia*, *Baeothryon pumilum*, *Beckmannia syzigachne*, *Carex appendiculata*, *Carex lithophila*, *Carex microglochin*, *Eriophorum brachyantherum*, *Equisetum palustre*, *Gentiana pseudoaquatica*, *Glyceria triflora*, *Kobresia myosuroides*, *Kobresia simpliuscula*, *Parnassia laxmannii*, *Pedicularis karoi*, *Pedicularis tristis*, *Thyselium palustris*, *Primula farinosa*, *Primula nutans* and *Ranunculus longicaulis*. The mire looks like the living one, but permafrost conditions are responsible for such slow linear increment of peat.

From past descriptions and local knowledge, we learned that these mires had previously occupied much more area. Climate fluctuations create dramatic changes in the mires. Part of the Darhad Kettle, which previously contained mires, now resembles a "lunar landscape". The former hollows are still filled with peat, and the basal layer of peat dates back to 400 years BP (410±40, GIN–12599). In these hollows, the same sedges as those encountered in the existing mire are found, but in a very suppressed living form. In between the hollows and on the ridges, vegetation is typical for steppe and gravel habitats.

Photo 19: The steppe and highland flora representatives are found on rocky shallow peat soils together with mire plant species.

Highland Blanket Bogs

Highland mires are the most intact peatlands in Mongolia. They cover small patches in watersheds at elevation higher than 2.500 m in the steppe zone, where steppe

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gives way to alpine tundra on slopes with water discharge or terraces. They are typical high mountain sloping blanket-bogs. Annual precipitation is more than 600 mm here. In most cases, these peatlands are associated with permanent or seasonally frozen bedrock. Typical bog vegetation is found here: sphagnum mosses, dwarf shrubs, sedges and cotton-grass presented by two species. Only some typically steppe plant species remind us that we are in Mongolia.

We described types, those in watersheds and those on slopes. The watershed bog was described from the Solongot Pass along the Khangay Ridge (48°16', 98°58'). Descriptions of the same bog types are known from PAVLOV (1929) and YUNATOV (1950). Having examined the floristic composition, Pavlov had presumed that, in certain places, those mires remained above than the last glaciation and served as refugia for various species groups. The floristic diversity is really very high here, and we have no other evidence to support the "refugia" theory. The peat deposits are not deep (up to 60 cm), date back to 1.300 years BP (1.310±60 GIN–12566), and are underlain by frozen gravel. Peat is built up mainly from sedges – at the bottom *Carex saxatilis*, and in upper parts *Carex artrofusca*. In the uppermost parts, cotton-grass and sphagnum mosses are found as macrofossils. Macrofossils of green mosses – *Aulacomnium sp.*, *Calliergon sp.*, *Polytrichum sp.* and *Tomentypnum sp.* are quite common in the peat. Willows are always present in the peat along the core. A description of the current vegetation structure follows: A large "cirque" surrounds a small spring in the middle of one of the slopes and the valley of the small brook runs out of the spring. The slopes are covered by dwarf shrub-cotton grass-*Sphagnum* vegetation. Some of the slopes have terraces on which hollow-hummock structures have begun to form. Sometimes, rock is on the surface and then the petrophytic group of species settles there. Along the brook, there are more shrubs, including willows (*Salix arctica*, *Salix berberifolia*, *Salix divaricata*, *Salix glauca*, *Salix rectijulis*, *Salix saxatilis*) and *Potentilla fruticosa*, a typical steppe species. Mosses are everywhere in the water on the stones; they are primarily species of *Calliergon giganteum* and *Fontinalis antipyretica*. Immediately surrounding the spring, we found typical spring mire vegetation: mosses *Calliergonella cuspidata*, *Paludella squarrosa*, *Philonotis fontana*, *Tomentypnum nitens*, and typical vascular plants such as *Cardamine parviflora*, *Carex dioica*, *Melandrium apetalum* and *Saxifraga hirculus*. The other habitat type is the small depression at the bottom of the cirque. Here, we found the deepest peat and sedge fens typical of highland valleys with mainly green mosses in the lower layer.

Photo 20: Sloping fens cover all small valleys in highlands

On the slopes, the dominating habitat type here, the following typical mire species are found: Agrostis *mongholica*, *Alopecurus turczaninovii*, *Angelica tenuifolia*, *Calamagrostis macilenta*, *Carex atrofusca*, *Carex coriophora*, *Carex enervis*, *Carex melanocephala*, *Carex orbicularis*, *Carex rigidioides*, *Carex saxatilis*, *Cirsium esculentum*, *Eriophorum humile*, *Eriophorum polystachyon*, *Gentiana pseudoaquatica*, *Juncus triglumis*, *Ranunculus longicaulis*, *Ranunculus repens*, *Salix divaricata*, *Stellaria palustris* and *Thyselium palustre*.

The slope blanket bog was described from the Beltesijn-gol tributary. It is situated on a rather steep (up to 30 degree) slope and is covered by dwarf willows, dwarf birch – *Betula fusca* and *Betula rotundifolia*, and a mix of shrubs with dominance of *Potentilla fruticosa* and *Rhododendron adamsii*. The ground vegetation is formed by sedges and other mire species (*Pedicularis karoi* and *Thyselium palustre*) and green mosses. Some typical spring mire species like *Saxifraga hirculus* and *Car-*

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Photo 21: *Pedicularis longifolia* recorded in mires of the Khangay Mountains and Darhad Kettle is known as typical for highland mires in Pamir and Tibet.

Photo 22: *Utricullaria intermedia* in Darhad Kettle mires is usual species for hollows the same as elsewhere in Eurasian mires.

Photo 23: Different species of *Juncus* and *Triglochin* occupy the usual ecological niche of *Scheuchzeria palustris*, found in Mongolia only in taiga zone.

damine parviflora are common here. It seems that mires of this type are fed by slope inflow, by groundwater discharge, and by atmospheric moisture (precipitation and mainly mist).

This brings us at last to the highlands, where we will finish our presentation on all the mire types that we have observed in Mongolia to date. The field study, together with cartographic analyses, offered us a picture of Mongolia's peatlands as being typical landscapes for the taiga and forest-steppe zones.

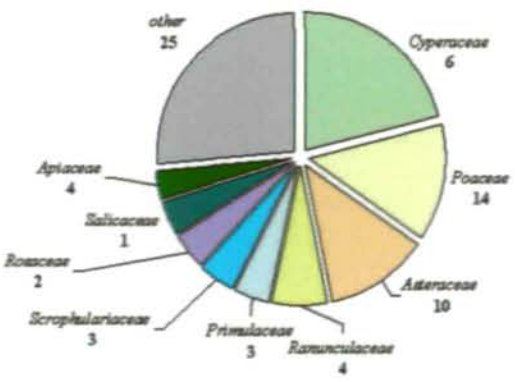

Fig. 2: Composition of the main familes in mires of Mongolia, by number of species (segments) and genera (figures) typical for mires within forest-steppe zone.

About What Does Mongolian Mire Flora Tell Us?

Mires were not very popular objects for floristic study. Besides, the applied scientific studies of pasture productivity and resistance encompassed the study of sedge fens. Less information is available for alpine blanket bogs and taiga sedge-*Sphagnum* bogs.

Vascular plant flora found in Mongolian mires includes 403 species, in 198 genus, and 62 families. Almost one-third (32.2%) of the species belong to 3 families: *Cyperaceae* – 51, *Poaceae* – 41, *Asteraceae* – 31; this composition is more typical for northern areas. Significant contributions are made by *Rosaceae* – 23, *Ranunculaceae* – 21, *Fabaceae* – 19, *Polygonaceae* – 15, and *Caryophyllaceae* – 10, adding features of steppe flora. Systematic analyses show that *Cyperaceae* is dominant in species diversity (39 species), as is common in mires. Four of them are new species for Mongolia (*Carex chordorrhiza*, *Carex lasiocarpa*, *Carex limosa*, and *Carex pauciflora*) The other most numerous genera are *Salix* (16) and *Artemisia* –

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Photo 24: *Aconitum glandulosum* – typical alpine species feels well also on the peat soils.

Photo 25: *Ligularia sibirica* grows in mires within taiga zone.

Photo 26: *Ligularia altaica* is typical for mires within forest-steppe zone.

8 species. Significant participation by *Poaceae* and *Asteraceae* is a feature of steppe and tundra of both critical and older habitat types. *Ranunculaceae* and *Apiaceae* – offer evidence of highly dynamic communities. Generally speaking, the systematic structure of Mongolian mire flora is typical for the Northern Holarctic floristic area. Herbaceous plants comprise the dominant living form (93%); shrubs are represented by 22 species and trees by 6 species.

Mire flora fully demonstrates the complicated dynamics of Mongolian mires, which under pressure from climate fluctuations and human impacts, compete with neighbouring habitat types, such as steppe, meadow, and gravel tundra. One of the particularities of the semi-arid climate is that wet-dry cycles are multi-year and individual cycles can last as long as ten years. During dry decades, peat accumulation stops, water shortages appear, and mire species take on a very depressed appearance. Thus, in the matter of a couple years, the community already resembles alpine meadow, steppe, or gravel meadow. But peat is still there, and within ten years, water returns and saturates the peat, mire plants look as they usually do, and plant-guests hide themselves among the natives. That is why flora analyses based on ecotypes demonstrate the presence of species of all ecological groups in the mires – from alpine gravel to dry steppe and salt marshes.

Mires and People in Mongolia

As we saw, mires in Mongolia are a typical landscape phenomenon. They have developed here over thousands of years and are integrated into the landscape as a considerable source of water. Mongolian peatlands constitute the last wet habitats in a considerable part of the country and are unique habitats that support special biodiversity.

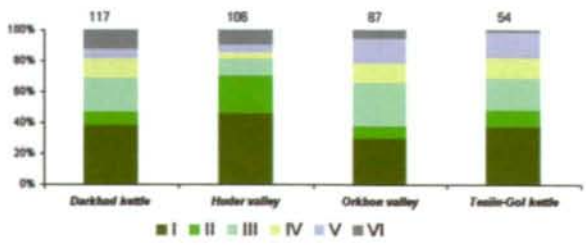

Fig. 3: Species Groups of: I – mires; II – meadow and forest; III – meadow-steppe; IV – dry steppe; V – salt marshes; VI – high mountains and gravel. The figures above the graphs represent the total number of vascular plant species recorded in mires at that site.

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Photo 27: Mires in Mongolia provide the most productive pastures; the Orkhon valley.

Peat deposits are not present in volumes necessary for industrial use, but they do have another significant role in the economy and social life – peat stores water. It stores water to maintain wet habitats and pastures, to feed rivers, to prevent soil erosion, to maintain levels of groundwater necessary for forest and crop growth, and to keep wells full of water. Mires and peatlands are used mainly for grazing and sometimes for arable lands. They are occasionally destroyed during road construction and gold panning in rivers.

Mires' role as pastureland in Mongolia is really outstanding. Dry periods can continue for years, and during those periods, the moisture preserved in mires due to the unique nature of peat, really becomes a source of life. The mires are living barriers on the road to desertification. Mires, which have been affected by people through overgrazing and drainage, will loose their ability to protect them from the desert.

Photo 28: Mires in Mongolia provide productive arable lands; the Huderijn-gol River valley.

Currently, mires are preserved within a number of nature reserves and Ramsar sites in Mongolia. There are no special protected areas devoted to mire protection, nor is there special site management regarding peatlands.

For thousands of years, Mongolians have traditionally lived in harmony with nature. However, global changes have thrust people into circumstances in which traditional knowledge is no longer comprehensive. Thus, the main threat to peatlands in Mongolia is the absence of detailed knowledge about their diversity, distribution, and natural functions. Peatlands use planning in Mongolia should be based on solid knowledge about their role in the landscape, including their catchment scale. We hope that the principle of wise use and age-old Mongolian traditions of living with nature will facilitate the identification of a rational balance between the utilization and conservation of these unique ecosystems, which are so vitally important to people.

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Zusammenfassung

Mongolische Moore: von der Taiga zur Wüste – Die vorliegende Arbeit gibt eine erste Übersicht über die Moore in der nördlichen und mittleren Mongolei. Sie setzt sich auch mit Arbeiten zu den mongolischen Mooren auseinander, die bis ins 19. Jahrhundert zurückreichen. Auf der Basis einer GIS-gestützten Auswertung der topographischen Karte konnte die Verbreitung der Moore in der Mongolei erarbeitet werden: 1.7 % der Landesfläche werden von Mooren eingenommen. Im Zuge von Feldarbeiten in den Jahren 2003 und 2004 wurden in characteristischen Mooren Untersuchungen zum Relief der Moore, zur Torfstratigraphie, zur Entwicklung und zur gegenwärtigen Vegetation durchgeführt. Resultierend daraus wurden im Untersuchungsgebiet sieben ökologische Moortypengruppen beschrieben: Tal-Wiesen-Niedermoore der Steppenzone, Übergangsmoore in den Großen Tälern der Waldzone, Tal-Hangmoore des Berglandes, Torfmoos-Seggen-Hanghochmoore, bewaldete Kesselmoore und Bruchwälder der Taigazone, Übergangsmoore auf Permafrost und Hochland-Deckenmoore. In dieser Arbeit wird die Flora der einzelnen Moortypen in Relation zur Artenzusammensetzung und zu ökologischen Gruppen (funktionalen Gruppen) untersucht. Das große Artenspektrum in den Mooren wird als potentielle Reaktion von Pflanzengesellschaften auf die veränderlichen ökologischen Verhältnisse interpretiert. Die Moore des untersuchten Gebietes werden als Weideland und in manchen Bereichen als Ackerland genutzt und sie sind durch Übernutzung und die Einflüsse des Klimawandels beeinträchtigt.

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